EXPRESS MAIL CERTIFICATE

"EXPRESS MAIL" LABEL No: EV369817945US
Date of Deposit: 3-16-04
I hereby certify that this paper or fee and any papers referred to as being attached or enclosed are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above, addressed to: M.S. PATENT APPLICATION, Commissioner for Patents, PO Box 1450, Alexandria, Virginia 22313-1450.

Naghma Hall

APPLICATION FOR

UNITED STATES LETTERS PATENT

FOR

METHOD AND APPARATUS FOR AN ACOUSTIC PULSE DECAY DENSITY DETERMINATION

Inventors: Rocco DiFoggio

Assignee: Baker Hughes Incorporated
3900 Essex Lane, Suite 1200
Houston, Texas 77027

Background of the Invention

Field of the Invention

The present invention relates generally to the field of fluid density measurements for a hydrocarbon or brine sample and relates in particular to an acoustic method and apparatus for determining the density of an unknown fluid such as drilling mud, brine, or a hydrocarbon in a downhole environment.

Summary of the Related Art

In various industrial processes that involve fluid material, it is useful to know the properties of the fluids involved. These fluid properties include, for example, density, compressibility, and acoustic impedance. Knowledge of the values of these various properties can be used to adjust process parameters or warn of impending calamity. In many applications, such as oil and gas well (borehole) drilling, fluid density is of particular interest. It is important to know or at least estimate the density of drilling fluid (also referred to as drilling mud) during a drilling operation, in order to prevent a blowout of the well caused by reduced mud weight resulting from incursion of natural gas into the drilling mud.

In a drilling operation, drilling fluid is pumped down the drill string (essentially a very long pipe) and exits at the drill bit. The drilling fluid then returns to the surface within an annulus formed between the outside of the drill string and the inside of the borehole. As the drill bit burrows into the geologic formations, the bit passes through zones containing various fluids. These zones can include saltwater, oil (hydrocarbons), lightweight fluids such as natural gas. If the pressure within the zone is greater than the pressure within the borehole, these fluids will enter the borehole and mix with the drilling fluid. As lightweight fluids mix with drilling fluid, the average density of the drilling fluid decreases. If the total weight of fluid within the borehole

decreases too much, it can lead to a blowout when a high-pressure zone is entered. It is therefore very important that the density of the drilling fluid be accurately monitored. In producing wells, the local fluid density, along with other measurements, can be used to infer the proportions of oil, water and natural gas that the well is producing at various depths in the well.

Logging tools for measuring fluid density with varying degrees of success are well known in the art. One commonly known technique for measuring drilling fluid density involves the use of acoustic transducers, particularly ultrasonic transducers, as described in U.S. Pat. No. 4,571,693 (the '693 patent). The device described in the '693 patent provides an ultrasonic transducer coupled to the body of a probe. The ultrasonic device transmits and receives a first signal across a first solid/fluid interface and a second fluid/solid interface, in order to measure the sound velocity of the fluid. A second ultrasonic signal is provided as a reference signal generated by reflection off the surface of a void within the device that is hermetically sealed from contact with the fluid. Measurements of the first and second signals, as reflected off the two surfaces are used to calculate reflectance and acoustic impedance, from which density of the fluid may be inferred.

Other known methods and apparatuses for measuring the fluid density in boreholes, such as those described in U.S. Pat. Nos. 4,939,362 and 5,204,529, include the use of either chemical radioactive sources or electrically-controlled radioactive sources (e.g, pulsed neutron source), which present clear environmental and health hazards. It is therefore apparent that a need exists for an improved acoustic well logging tool and method to determine the density of drilling fluid and hydrocarbon sample associated with downhole operations in the borehole.

Summary of the Invention

The present invention addresses the shortcomings of the related art discussed above. The present invention provides an accurate measurement of fluid density in a downhole environment. The present invention places an acoustic transducer in contact with a "near wall" whose acoustic impedance is much different than the impedance of the fluid to be measured. The transducer launches an acoustic pulse into this near wall (such as a plate, a wall of a tube, or a wall of a sample chamber). The other side of this near wall is in contact with a sample of unknown fluid. After sending out an acoustic pulse, this same transducer acts as a receiver to monitor the reverberations of this acoustic pulse within this near wall.

Each acoustic pulse contains many amplitude cycles so we subdivide the pulse into many small time windows (e.g., 4 ns each) and integrate the square of the acoustic amplitude in each small time window over the entire duration (e.g., 500 ns) of a pulse to obtain a measure of the energy contained within that pulse. The duration of the pulse has been called the "transducer ringdown time" by others ('962 lines 21-25 of col. 5). In the present invention, we use all the amplitude values within a pulse and so average out measurement errors in any single amplitude value. Further refinements to this calculation can be made by subtracting the integrated root-mean-square noise from the energy in each pulse. This RMS noise can be estimated from the observed noise between pulses.

As the acoustic pulse bounces back and forth within the near wall, each echo of this original pulse loses the same fraction of energy on each round trip. That is, the energy contained within each successive echo decays exponentially. Therefore, we plot the logarithm of the energy in each pulse packet against echo number and calculate the slope. The process of calculating a least-squares-fit slope over many points averages out any small random errors in the

individual points being used and so improves the accuracy of the measurement compared to a single-point measurement.

As can be seen from Figs. 2-4 of the present invention, the reflected acoustic energy is not concentrated into a single cycle as shown in the idealized illustration of Fig. 2 of '693 but is distributed over several cycles. Also, the distribution of reflected energy between the largest amplitude cycle and its neighboring cycles within the same pulse is not constant but changes from pulse to pulse and reflection to reflection, which could be a significant source of inaccuracy in the '693 measurement.

Using a series of 3-5 pulse echoes, a substantially well-fitted slope of the logarithm of the pulse energy decline versus the pulse echo number is generated. This slope represents the product of the reflection coefficient at one face of the near wall (the face that is in contact with the fluid) multiplied by the reflection coefficient at the other face of the near wall (the face that is in contact with the transducer).

In an air-filled titanium tube, ignoring small effects of attenuated reflection due to air's high absorption of ultrasound, the reflection at the air/wall interface is approximately 100% because titanium, or any metal, has substantially greater acoustic impedance than air. Thus, we can calculate the reflection coefficient at the transducer/wall interface using the pulse energy decline slope of an air-filled tube as a reference value. Then, using this reflection coefficient at the transducer/wall interface, we can then calculate the reflection coefficient at the fluid/wall interface for an unknown fluid from the slope of the logarithm of the pulse echo energy versus pulse echo number. Because we know the acoustic impedance of the wall material, we can then use the measured reflection coefficient at this fluid/wall interface to calculate the acoustic

impedance of the unknown fluid. Finally, we calculate the fluid's density by dividing its measured acoustic impedance by its measured sound speed as explained immediately below.

A far wall reflector is placed in contact with the fluid at some known distance away from the near wall and the time to receive its reflection is measured. This distance is chosen to be large enough that the reflection off this far wall occurs at much later times, when reverberations of echoes within the near wall have become negligible. When practicing this invention using a sample chamber, this far reflector simply becomes the inner face of the opposite wall of the chamber that is in contact with the fluid. For example, the chamber can be a thick-walled hollow tube. Then, from the measured round trip travel time in the fluid and the known inner diameter of the tube, the speed of sound for the fluid can be calculated.

Thus, the density of an unknown fluid is determined from the reflection coefficient at the wall/fluid interface, the acoustic impedance of the wall material, and the sound speed of the fluid. Additional features and advantages of the invention will be evident from the following specification and figures.

Brief Description of the Drawings

The following figures show an example of the present invention in which like elements in different figures bear the same reference numerals.

FIG. 1 illustrates a laboratory validation experiment in which the density of two fluids, dodecane and water, were determined to demonstrate some of the principles of the present invention;

FIG. 2 illustrates the pulse energy decay for an acoustic pulse bouncing back and forth inside of the tube wall while the sample tube is filled with air;

FIG. 3 illustrates the pulse energy decay for an acoustic pulse bouncing back and forth inside of the tube wall while the sample tube is filled with dodecane;

FIG. 4 illustrates the pulse energy decay for an acoustic pulse bouncing back and forth inside of the tube wall while the sample tube is filled with water;

FIG. 5 illustrates the slope for pulse energy decay for acoustic pulses shown in **Figs. 2, 3** and **4**;

FIG. 6 illustrates a comparison of calculated to actual density for the present invention;

FIG. 7 illustrates a schematic representation of the present invention showing the transducer/pulser, processor and sample flow line of an exemplary embodiment of the present invention;

FIG. 8 depicts a schematic representation of a density measuring instrument disposed from a wire line in a well bore drilled through an earth formation;

FIG. 9 depicts a schematic representation of a density measuring instrument disposed form a drill string in a well bore drilled through an earth formation;

FIG. 10 illustrates an example of the functions performed by the present invention; and

FIG. 11 shows the poor results of applying the method of '962 patent compared to the lab verification experiment of the present invention.

Detailed Description of an Exemplary Embodiment of the Present Invention

The present invention provides a method and apparatus for a real time downhole fluid density measurement. The invention is applicable to the determination of fluid density for use in association with wire line and monitoring while drilling applications.

Turning now to **FIG. 1**, in a laboratory simulation of the present invention, a small 10 MHz transducer **101** was attached to the outside wall **102** of a titanium alloy sample tube **100**. As shown in **FIG. 1**, the sample tube **100** had dimensions of 0.218" internal diameter **109** and walls of 0.110" thickness **108**. After the transducer **101** was pulsed, acoustic reflections **202, 204, 206** and **208** were monitored using this same transducer **101**. The laboratory validation experiment was performed having different substances **106** filling the sample tube. The experiment was performed for air, oil, and water filling the tube. These experiments are as shown in **Figs. 2, 3**, and **4** respectively below. As shown in **FIG. 3**, the sample tube is filled with dodecane and an acoustic pulse transmitted from transducer **101**. After the transducer **101** was pulsed, the acoustic pulse echoes **302, 304, 306** and **308** were monitored using this same transducer **101**. To be able to clearly separate the pulses, the pulse duration should be shorter than the time spacing between successive pulse echoes. If necessary, the near wall **104** can be locally thickened where the transducer contacts it to create a "standoff" of the same material, which would then serve to lengthen the time spacing between successive pulses. As shown in **FIG. 4**, the sample tube is filled with water and an acoustic pulse transmitted from transducer **101**. After the transducer **101** was pulsed, acoustic pulse echoes **402, 404, 406** and **408** were monitored using this same transducer **101**. The slope of logarithm of the pulse echo energy decay as the acoustic pulse bounces back and forth within the near wall **104** of the tube contacted by the

transducer **101** is a measure of the acoustic impedance (sound speed times density) of the fluid filling the tube as shown in **Figs. 3** and **4**.

As shown in **FIG. 3** and **4**, as the acoustic pulse bounces back and forth within the wall **104** of the tube, the energy contained within successive pulses drops by the same factor, representing an exponential decline. Wall **104** of the tube is referred to as the "near wall" because it is the wall closest to the transducer. In the example of the invention a processor monitors the reverberation of acoustic pulses within this near wall to determine the acoustic impedance of an unknown fluid in contact with the opposite face of this wall. The area under the square of the amplitude of each pulse is a measure of pulse energy. With a series of 3-5 pulses **302, 304, 306, 308** or **402, 404, 406, 408**, a substantially well-fitted slope **502, 504,** or **506** respectively of the logarithm of the pulse energy decline versus the pulse number is generated. The slope goes as the logarithm of product of the intensity reflection coefficient at the near-wall/fluid interface **107** multiplied by the reflection coefficient at the near-wall/transducer interface **108**. Ignoring the effects of attenuated reflection due to air's high absorption of ultrasound, then the reflection at the near-wall/air interface **107** is approximately 100% because titanium, or any metal, has substantially greater acoustic impedance than air.

Using the pulse energy decay slope **502** of the air-filled tube **100** as a reference value and ignoring any attenuated reflection, the reflection coefficient at the transducer/near-wall interface **108** can be calculated and subsequently used to determine the reflection coefficient at the near-wall/fluid interface **107** for an unknown fluid. The speed of sound for the fluid inside of the tube **100** is calculated from the round trip travel time for the reflection off the far-wall/fluid interface **113** of the tube **100** and the round trip distance across the inner diameter **109** of the tube. The first pulse echo from the far-wall/fluid interface **113** is followed by subsequent reverberation

echoes within the far wall of the tube that are much smaller in amplitude and thus harder to detect and measure. Finally, we calculate the density of an unknown fluid from the reflection coefficient at the near-wall/fluid interface **107**, the acoustic impedance of the near-wall material, and the speed of sound in the fluid.

In the laboratory validation experiment, a 10 MHz Panametrics **101** acoustic transducer, including a processor and pulse generating electronics **116** and a titanium sample tube **100** having a 0.218" inner diameter **109** and 0.110" wall thickness **108** were used to demonstrate the calculation of density in accordance with the present invention. Although a round tube was used in this verifying lab experiment, a tube having rectangular inner and/or outer cross sections that are parallel could also be used. Mounting the transducer against a flat face on the outside of the tube increases the amount of acoustic signal transmitted into it and having parallel inner faces reduces uncertainty in round trip pathlength associated with a sound ray not traveling exactly along the diameter of a circular cross section tube. The following parameter definitions are germane to the following discussion of the present invention.

ρ_T = Transducer density in g/cc

c_T = Transducer longitudinal sound speed

ρ_W = Transducer wall density in g/cc

c_W = Tube wall longitudinal sound speed

ρ_F = Fluid density in g/cc

c_F = Fluid sound speed

R_{TW} = Fraction of energy reflected at Transducer/Wall interface

R_{WF} = Fraction of energy reflected at all/Fluid interface

Specifically,

R_{WA} for Wall/Air

R_{WH} for Wall/H_2O

R_{WO} fro Wall/Oil

The energy of each successive pulse echo depends only on the fraction of energy reflected at each interface. That is,

$E_{reflected}$ is proportional to $(R_{TW} R_{WF})^1$ for the 1^{st} bounce within the tubing wall (1)

$E_{reflected}$ is proportional to $(R_{TW} R_{WF})^2$ for the 2nd bounce within tubing wall (2)

$Y = E_{reflected} = k\,(R_{TW} R_{WF})^X$ for the X^{th} bounce within tubing wall, (3)

where k is a proportionality constant.

Therefore,

$\ln(Y) = X \ln(R_{TW} R_{WF}) + \ln(k) = m X + b$

(4)

Where the slope $m = \ln(R_{TW} R_{WF})$, and the intercept $b = \ln(k)$.

Assuming that no energy is absorbed at the transducer/wall or at the wall/fluid interface, then the reflected energy fractions, R_{TW} and R_{WF}, are given by,

$$R_{TW} = (\rho_T c_T - \rho_W c_W)^2 / (\rho_T c_T + \rho_W c_W)^2 \quad (5)$$

$$R_{WF} = (\rho_W c_W - \rho_F c_F)^2 / (\rho_W c_W + \rho_F c_F)^2 \quad (6)$$

$$\rho_F = \rho_W (c_W / c_F)\,[1 + \mathrm{Sqrt}\,(R_{WF})] / [(1 - \mathrm{Sqrt}\,(R_{WF})] \quad (7)$$

FIG. 5 shows the slopes, $m = \ln(R_{TW} R_{WF})$, for air **502**, dodecane **504**, and water **506**. If we assume that there is no attenuated reflectance at the near-wall/air interface **107**, then (because

the acoustic impedance of titanium is much greater than that of air) the fraction of energy reflected is given by,

$$R_{WF} = R_{WA} \approx 1 \qquad (8)$$

Thus,

$$m_{Air} \approx \ln(R_{TW}) \qquad (9)$$

$$R_{WF} \approx \exp(m_{Fluid}) / \exp(m_{air}) \qquad (10)$$

$$R_{WO} \approx \exp(m_{oil}) / \exp(m_{air}) \qquad (11)$$

$$R_{WH} \approx \exp(m_{H2O}) / \exp(m_{air}) \qquad (12)$$

Substituting R_{WO} for R_{WF} and c_O for c_F in Eq. 7, we obtain the density of oil as,

$$\rho_O = \rho_W (c_W / c_O) [1 + \mathrm{Sqrt}(R_{WO})] / [(1 - \mathrm{Sqrt}(R_{WO})] \qquad (13)$$

Similarly, substituting R_{WH} for R_{WF} and c_H for c_F in Eq. 7, we obtain the density of H_2O as,

$$\rho_H = \rho_W (c_W/c_H) [1 + \mathrm{Sqrt}(R_{WH})]/[(1-\mathrm{Sqrt}(R_{WH})] \qquad (14)$$

FIG. 6 illustrates a plot **602** of the calculated densities of oil (ρ_O) and of water (ρ_H) (see, equations 13 and 14 above) and the assumed (zero) density of air against the actual densities of these fluids. The correlation coefficient, R^2 = .9996, is quite good, thus it is clear from the laboratory validation experiment that the method and apparatus of the present invention correlates the actual density to the calculated density.

Finally, because the acoustic attenuation of fluids increases with their viscosities, we can, in principle, estimate fluid viscosity by measuring the attenuation across the inner diameter of the tube. The attenuation can be inferred from the discrepancy between the actual reflected signal and the expected value of an unattenuated reflected signal as calculated from measured R_{TW} and

R_{WF}). To be sure of actually monitoring attenuation, to the example of the present invention uses acoustic pulses at more than one frequency because the attenuation increases as a power of frequency.

According to Dr. Mark Davidson of the University of Plymouth's Institute of Marine Studies (http://freespace.virgin.net/mark.davidson3/TL/TL.html), for water, viscous friction is the dominant mode of attenuation at frequencies above 1MHZ and an approximate expression for the attenuation coefficient (α_1) for fresh water due to viscous friction alone is:

$$\alpha_1 = [2.1 \times 10^{-10} (T\text{-}38)^2 + 1.3 \times 10^{-7}) f^2 \text{ dB/m} \qquad (15)$$

where T is the temperature (centigrade) and f is the frequency (kHz).

M. Kekawy, H. Afifi, and Kh El-Nagar (National Institute for Standards, Egypt, http://symp15.nist.gov/pdf/p567.pdf) related the acoustic attenuation coefficient, α, for oil to its viscosity, η, using the equation

$$\eta = \rho\, \alpha\, c^3 / 26.3 f^2 \qquad (16)$$

where ρ is the oil's density, c is the oil's sound speed and f is the frequency of the sound. Using the density, sound speed, and attenuation measured by the present invention and knowing the frequency, we can calculate the viscosity using Eq. 16. In practice, we expect that the round trip travel distance in the fluid would need to be increased substantially beyond the 0.436" of our lab verification experiment to make the viscous attenuation large enough to be accurately measured.

Turning now to **FIG. 7**, the present invention comprises a transducer **701**, a sample flow line **703** or sample flow path **705** containing a fluid sample for measuring fluid density and sound speed of the fluid **708** inside of the tube or sample flow path or sample tank **711**. The thickness **707** of the flow line wall **706** is known. A processor **702** and pulsing electronics **704** are provided to send an acoustic pulse from pulser **701a** through wall **706** into fluid **705** in flow path **705** or

from pulse **701b** through wall **706** of thickness **707b** to sample chamber **711**. The transducer **701** receives echoes from the acoustic pulse, which are monitored by the processor. The present invention further comprises a wall standoff, which is an acoustic spacer interposed between the transducer and the wall that is made of the same material as the wall. This spacer simply increases the round trip distance and corresponding travel time for pulse-echo reverberations within the combined standoff plus near-wall material. It serves to lengthen the time between successive decaying echo pulses and so it serves to improve pulse separation, to avoid overlap of pulses and to improve quantification of energy in each pulse. The processor determines the density of the fluid in the sample flow line by performing the functions described in **FIG. 10**.

Turning now to **FIG. 8**, an example of the current invention deployed from a wire line **802** in a borehole **804** drilled in a formation **800**. An extensible probe **801** extracts fluid from the formation **800**. The extracted formation fluid flow through flow line **705** into sample tank **711** where the density determination module **700** of the present invention determines the density of the formation fluid. Stablizers **703** hold the tool **50** and extensible probe **801** in place during extraction of formation fluid. The results of the density determination are acted on by processor **702** or the results are sent to the surface **51** to be acted on by surface processor and control **1000**.

Turning now to **FIG. 9**, another example of the current invention is shown deployed from a drill string **901**. Straddle packer **903** hold tool **50** in place during the entry of fluid through flow path **705** to density device **700**. The fluid can come from the annulus **805** between the tool **50** and the well bore **804** or from the formation **800**. Fluid can be routed to the sample tank **711** or back to the well bore annulus **805** as desired based on the results of the density determination performed by the present invention **700**. The results of the density determination can be acted on

by processor **702** or the results can be sent to the surface **51** to be acted on by surface processor and control **1000**.

Turning now to **FIG. 10**, an example of the functions performed by the present invention is illustrated. As shown in block **1001** the present invention captures a fluid sample in a flow line from the formation or the borehole. In block **1003** the present invention then sends an acoustic pulse into the fluid sample in the flow line or sample tank. The processor of the present invention then monitors the echo returns within the wall of the flow line or sample tank and integrates the energy of each acoustic echo pulse. The processor determines the slope of the decay of the integrated acoustic echo pulses bouncing inside of the wall of the flow line. In block **1007** the present invention then determines the reflection coefficient for the inner wall/fluid interface. In block **1009** the present invention determines the speed of sound in the fluid. In block **1011** the present invention determines the density of the fluid in the line as described above. In block **1013** the present invention determines the viscosity of the fluid in the flow line as described above.

The present invention provides a method and apparatus for real time downhole fluid sound speed and real time downhole fluid density. Monitored over time, this can serve as a measure of fluid sample cleanup as the fluid is pumped form the formation. The measured fluid density will initially change more rapidly and eventually change more slowly over time as the fluid cleans up to it asymptotic limit. Similarly, viscosity changes over time can be used to monitor cleanup.

The preferred embodiment of the present invention provides an acoustic pulsing device on the outer wall of a small sample flow tube through which fluid from the formation or wellbore is being pumped. This sample tube wall is not thick enough to allow for an internal reflection

slot (a void) of the type described in U.S. patent number 6,189,383 (the '383 patent). Also, the time windows for integration in the '383 patent (**Figs. 5** and **6** of '383) are overlapping and they include more than one pulse echo unlike the present invention, which requires that integration be done over each individual pulse without any overlap. The present invention fits a line between the echo number and the logarithm of the energy in each echo, which is not possible if one integrates over more that one pulse echo, as is done in the '383 patent. The present invention does not need an internal reflection slot because it is the slope of this best fit line that indicates the acoustic impedance of whatever fluid is in contact with the tube.

The present invention is more accurate than prior attempts to determine density of unknown fluids such at that described U.S. patent number 5,741,962 (the '962 patent). In the '962 patent, reflection coefficients and the corresponding fluid density are calculated from peak-to-peak amplitudes (**FIGS. 4A** and **4B** of the '962 patent), which can be very unreliable and prone to aliasing, sampling, and other experimental measurement errors. **FIG. 11** shows the poor results of applying the method of '962 patent to the lab verification experiment of the present invention. It plots the logarithm of the square of the maximum amplitude swing within once cycle against pulse echo number. Now, instead of the high coefficients of determination (R^2>0.99 in **FIG. 5**) obtained by the pulse-integration method of the present invention, the coefficients of determination vary from $R^2 = 0.65$ to $R^2 = 0.73$ and the points do not lie close to the best fit lines **1102**, **1104**, and **1106**. The reason is that the '962 patent, like '383 patent, describes using an idealized signal for illustration. Only if the pulse shape remained completely unchanged from pulse-to-pulse (or from echo-to-echo of a single pulse) would the square of the peak-to-peak amplitude remain proportional to the integrated peak energy. However, from the experimental data in Figures 2-4 of this invention it is clear that successive pulse echoes are not

simply rescaled copies of the previous pulse but that they undergo distortion, which causes the square of the peak amplitude swing to be an unreliable indicator of total pulse energy. The present invention estimates the energy under an entire pulse rather than relying on a single transient peak amplitude. Thus the present invention provides a more accurate method and apparatus than relying on a transient peak amplitude as in the '962 patent.

In another embodiment of the present invention, the method of the present invention is implemented as a set computer executable of instructions on a computer readable medium, comprising ROM, RAM, CD ROM, Flash or any other computer readable medium, now known or unknown that when executed cause a computer to implement the method of the present invention.

While the foregoing disclosure is directed to the preferred embodiments of the invention various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope of the appended claims be embraced by the foregoing disclosure. Examples of the more important features of the invention have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto. The above example of a preferred embodiment has been provided for illustration purposes only and is not intended to limit the scope of the invention, which is determined by the following claims.